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(54) OPERATIONS UNDER WATER

(71) We, BATTELLE MEMORIAL INSTITUTE, a Body Corporate organised under the laws of the State of Ohio, one of the United States of America, having laboratories and offices at 7 route de Drize, 1227 Carouge, Geneva, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

Underwater operations are undergoing a considerable expansion linked to the increase in prospecting for and working of hydrocarbon deposits at sea by offshore technology. The essential part of the manufacturing and construction operations involved in platforms or underwater pipelines is at the present time carried out outside the water. However, certain installation and maintenance operations can only be effected under water.

This is particularly so in the case of welding, oxygen torch cutting, the application of certain coatings by plasma spraying, spray-painting, etc. Of these operations, arc welding without doubt poses a particularly complicated problem because of the disturbing influence of water on the welding process, in particular on the arc stability, which has repercussions on the weld quality. The welding arc behaves differently under water than in free air. As soon as the arc is established under water, the combustion of the electrode coating materials and the evaporation and decomposition of the water form gas bubbles around the arc. When the pressure of these bubbles become sufficient, they leave the arc region and rise towards the water surface. The current thus created affects the arc stability. The hydrogen originating from the decomposition of the water by the effect of the heat emitted by the arc penetrates into the molten metal and makes the weld seam more fragile. The presence of water causes tempering of the weld seam due to the sudden cooling which it produces.

Various attempts have been made to remedy these disadvantages. One of these consists in recreating the welding conditions existing out of the water, by means of a controlled atmosphere in a sealed enclosure adjacent to the surface to be welded. This enclosure is designed to receive the welder, which requires a large volume.

This method is extremely costly and inflexible, i.e. it is not possible to move the enclosure during the course of the operation. Each movement means breaking the seal, recreating the seal, and reforming a controlled atmosphere, with all the difficulties, time losses, and work which these operations entail. The welding methods used in such an inhabited enclosure are limited essentially to the tungsten inert gas (TIG) process, in which no filler metal is used, and possibly the metal inert gas (MIG) process, but welding with slag cannot be used because of the emission of harmful gas which would make the atmosphere in the enclosure or bell unbreathable and cause poor visibility.

According to a further proposal, a small hemispherical bell of the order of 5 cm diameter is held against the surface to be welded, and through it the electrode is inserted, and the gas produced during welding is used to remove the water from the proximity of the arc. This experimental process has given good results with coated electrodes where the coating contains a high proportion of powdered iron, but presents difficulties on an industrial scale. It is sensitive to spatial orientation, because of gravity, and is limited to electrodes capable of producing a sufficient volume of gas.

The fumes filling the bell during welding make visibility poor. Finally, the process is limited to one particular welding operation with the exclusion of any other operation which does not evolve gas.

Finally, French Patent No. 2 197 689 and German Patent No. 2 342 648 propose a welding torch for underwater welding, surrounded by a double bell the respective edges of which are inclined outwards and define therebetween an annular nozzle. The space between the two bells is connected to a source of water under pressure, while the bell interior is connected to a source of inert gas such as argon. When the pressurised water is introduced into the space between the two bells while the welding torch is submerged, the water leaves this space through the annular nozzle to form an outwardly inclined sheet. This sheet creates a pumping effect on the fluid inside the bell. As the argon or other welding gas is fed into the bell simultaneously, an inert atmosphere is formed. However, to maintain this gas pocket the pumping action of the water sheet must be uninterrupted, so that once the water is evacuated from the bell it is the gas that is pumped, the water being prevented from reentering the bell in that an outflow from the interior of the bell opposes it. The stability of the gas pocket thus formed is directly dependent on the speed of flow of the water sheet. The higher this speed, the greater the pumping effect, so that the gas consumption grows on the one hand as a function of this speed, and on the other hand proportionately to the depth. High gas consumption is an obstacle in underwater welding processes, because visibility decreases as a function of the quantity of bubbles escaping from the bell. This is one of the problems encountered by this process, and has only been solved by creating an automatic welding station with remote control, necessitating a costly installation which is complicated in use. Moreover, this process is very sensitive to the position of the bell, and the formation of the gas pocket with the bell aperture vertical has proved very difficult.

The object of the present invention is to provide a method which at least partly remedies the disadvantages of known processes.

To this end, the invention firstly comprises a process for replacing, with a volume of gas, a corresponding volume of liquid in a submerged enclosure surrounded by a bell of which the internal space has an axis of rotational symmetry, and a surface disposed facing the opening in said bell, wherein said volume of liquid is expelled by increasing its pressure relative to the pressure of the surrounding liquid and this process is characterised in that the mass of liquid contained in the bell is given a vortex movement substantially coaxial with the said axis of the bell, and at least one escape passage is provided in proximity to the edge of said bell to force the liquid to escape from said bell by centrifugation, and gas under pressure is simultaneously fed into said bell.

The invention also comprises a device for effecting said process, characterised in that it comprises a bell, a conduit for connecting this bell to a source of gas under pressure, and means for creating a vortex movement of the liquid contained in the bell.

Finally, the invention includes an application of this process for effecting an arc welding operation on said surface facing the opening of said bell, the arc being formed in the volume of gas created inside the said bell.

The main advantages of this invention are immediately obvious. They are its insensitivity to position, the creation of a controlled atmosphere, the possibility of making a continuous weld on a dry surface, and the creation of a working region of good visibility. Further, advantages of the invention will be mentioned hereinafter.

The accompanying drawing illustrates, very diagrammatically and by way of example, two embodiments and modifications of the device for effecting the process according to the present invention.

Figure 1 is a view of an underwater welding installation.

Figure 2 is a vertical section through a first embodiment of a welding torch.

Figure 3 is a view similar to Figure 2 showing a second embodiment.

Figure 4 is a view similar to Figure 2 showing a modification of the embodiment of Figure 2.

Figures 5 and 6 show two applications of the process for welding lapped pieces and pieces forming a right angle respectively.

Figure 7 is a metallographic representation of a weld made by the process according to the invention.

Figure 1 shows one particular application of the process according to the invention, for welding an underwater pipe. This Figure shows a pipe 1 which a diver is in the process of welding with an arc welding torch 2 provided with the device for effecting the process for forming a pocket of gas adjacent to the surface of the pipe 1. To this end, the torch 2 is connected to a welding station 3 situated on a barge 4, by a complex connecting conduit 5 comprising an electrical conductor for connecting the welding electrode to the voltage source on the welding station 3, a pipe for feeding the torch with welding gas under pressure, the source of which gas forms part of the welding station 3, and a pipe fed by a pump P, the purpose of which will be explained hereinafter.

Figure 2 is a more detailed view of the end of an arc welding torch 2 associated with a device 6 for effecting the process for forming a pocket of gas adjacent to the portion of surface S to be welded The device 6 comprises a bell 7 of acrylic rein e.g. "Plexiglas" (registered Trade Mark), "Perspex" (registered Trade Mark) or other transparent material if it is required to see the working region, and mounted at the end of a torch 2 comprising an electrode 8 housed in a tubular sleeve 9 forming a gas feed conduit 10 connected to the welding station 3 of Figure 1 by the gas feed pipe of the complex conduit 5. The internal space of the bell has an axis of rotational symmetry which, in Fig. 2, is vertical.

Bearings 11, only one of which is shown in Fig. 2, are disposed between the sleeve 9 and bell 7 to enable the latter to rotate about the said axis. The upper end of this bell has an annular projection constituted by blades 12 disposed at the outlet of a spiral chamber 13 fast with the sleeve 9 and fed by a conduit 14 connected to the pump P of Fig. 1 by a pipe of the complex conduit 5. Finally, a baffle 16, the purpose of which will be explained hereinafter, is fast with the sleeve 9 and extends radially relative to the axis of the bell 7. The formation of the pocket of gas is obtained by placing the bell in proximity to the surface S without resting the bell 7 against the surface. The tool may be provided with a rest to fix a certain distance between the edge of the bell 7 and the surface S. However, it will be clear subsequently that such a rest is not essential. It may be useful, particularly when the edges of the plates to be welded are irregular, to place a shield 15 on the side opposite the welding side, in order to reduce the flow of water drawn into the bell 7 through the gap separating the plates to be welded. The spiral chamber 13 is fed with water under pressure, if the surrounding liquid is water, as in nearly all applications, and simultaneously the conduit 10 is fed with gas, the nature of which may vary according to the type of welding. The pressurised water leaving the chamber 13 encounters the blades 12 which transform this water pressure into a tangential force applied to the bell 7 to turn it in the direction of the arrow F. The rotation of this bell is progressively transmitted by friction to the water, in particular the water situated in the bell 7. The vortex movement of the water creates centrifugal forces which tend to evacuate the water through the passage formed between the edge of the bell 7 and the surface S of the piece to be welded. As gas under pressure is simultaneously fed into the bell through the conduit 10, the water leaving the bell 7 is replaced by gas, creating a pocket of gas inside the bell, which enables the arc formed between the electrode 8 and the surface S to operate in a controlled atmosphere, the composition of the gas being known. Once the water has been expelled from the bell and the gas pocket has formed, the rotation of the bell serves to maintain equilibrium between the surrounding water and gas pocket. The gas flow is, of course, constant so that bubbles escape continuously from the bell 7. Because of the rotation of the water, the bubbles are also made to rotate so that they describe a sort of helix in the direction of the arrow F as they emerge from the bell 7. To give a region of good visibility, the radial baffle 16 is placed to intercept the bubbles, so that a zone of good visibility is preserved on the other side of the baffle 16. This is obviously only one of the means which can be conceived for solving the visibility problem.

The second embodiment shown in Fig. 3 differs only slightly from the preceding. In this second case, the bell 7a is fixed relative to the tubular sleeve 9, and the vortex movement is produced by tangential admission of water into the bell. Blades 12a are disposed inside the bell 7*a* between the tubular sleeve 9 of the torch 2 and the inner face of the bell, at the outlet of a spiral chamber 13a provided in the bell and fed by a conduit 14a connected to the pump P of Fig. 1 by a tube of the complex conduit 5. The torch itself is absolutely identical to that of Fig. 2. In this second embodiment, the water leaving the spiral tank 13a under pressure is provided with a vortex movement transmitted to it by the inclination of the direction blades 12a which are fixed. This water progressively transmits a vortex movement to the fluid contained in the bell, this movement inducing centrifugal forces which cause the water to leave the bell, the water then being replaced progressively by the gas fed through the conduit 10. An equilibrium condition is established in which the bell contains a pocket of gas surrounded by a film of water lying against the walls of the bell, as shown in the drawing. The presence of this film of water against the inner face of the bell provides protection against weld spatter and ensures that the bell remains transparent and consequently that the welding zone remains visible.

Fig. 4 shows a modification of the embodiment of Fig. 2, in which the edge of the bell 7 comprises an annular rim carrying uniformly distributed tufts of hair 17. These tufts are separated by spaces which enable the water and gas to leve the bell. Furthermore, they enable the bell to adapt itself better to the irrgularities of the surface to be welded. The presence of these tufts helps equilibrium to be established between the water surrounding the bell and the internal pocket of gas. In contrast to the aforementioned prior art process which uses a pumping effect, the centrifugation utilised in the process according to the invention enables equilibrium to be established between the inside and outside of the bell without any outflow where the two media come together. A certain gas consumption is necessary, to be sure, for the welding process in order to create a controlled atmosphere for arc formation, but the stability of the gas pocket does not depend on the speed of discharge of the gas. Consequently, the bubble density can be reduced and visibility improved.

The utilisation of the process according to the invention is obviously dependent on maintaining a uniform space between the edge of the bell and the surface facing the bell opening. There are two other cases of welding than those previously illustrated, namely lap welding as shown in Fig. 5, and welding pieces at a right angle as shown in Fig. 6, in which the bell cannot always be utilised as it stands.

In these two cases, the difficulty can be overcome using wedges. Thus in the example of Fig. 5, a wedge 18 may be used, with channels 18a for a circulation of a cooling fluid so that the wedge does not become welded. In welding pieces at a right angle, a support plate 19 may extend the surface of one of the pieces to be welded in order to form a continuous surface opposite the bell opening.

Certain advantages of the present invention can be deduced from the preceding description. These include the fact that the welding may be carried out continuously by manual means, with good visibility, without the need for previous preparation. Different types of welding may be used, whether they produce gas and fumes as in the coated wire MIG processes, or do not produce gas such as the TIG processes, but require argon or helium for forming the arc plasma. The type of gas fed to the bell may be adapted to the arc welding process chosen. Slag processes can be used because of the continuous fume evacuation, while TIG processes can be used because of gas feed to the interior of the bell.

With the TIG process, the welder needs only to control the position of the bell during welding, the electrode position remaining fixed inside the bell.

With the MIG process, in which the electrode is a wire or rod which provides the metal, the electrode feed may be continuous. Welding machines are commercially available which are designed to adjust the welding parameters such as the arc voltage as a function of the arc characteristics. In this manner the welder controls only the positioning and translation movement of the welding bell. This simplifies the manual welding operation to the greatest possible extent.

The described process not only enables a controlled atmosphere to be created around the arc, but makes underwater welding almost as simple as welding out of water, as the process in practice requires no particular preparation. The formation of the gas pocket is almost instantaneous and welding can be immediately carried out. It should be noted that maintaining the distance between the edge of the bell and the surface to be welded does not pose any great problem as the bell encounters a certain resistance as it approches the surface to be welded, on the one hand because of the water centrifuging between the edge of the bell 7 and the surface S, and on the other hand because of the gas expelled from the bell. However, in order to guarantee a certain uniformity of the space between the edge of the bell and the surface to be welded, rests may be provided. These may be formed on the rim of the bell, as shown by the projections 7a of Fig. 3, where the bell is static. If the bell is of the rotatable type, a tripod (not shown) may be fixed on the tubular sleeve 9. However, a skilled worker could dispense with such guides. With the modification shown in Fig. 4, the brush hairs are applied against the surface to be welded and precisely fix the distance between the electrode and this surface. The process may be carried out in any position of the bell, whether its axis of revolution is vertical or horizontal, and whether the surface to be welded is below or above the bell. This insensitivity of the process to the force of gravity constitutes without doubt one of its most important characteristics. In this respect, up to the present time only processes using sealed bells have this advantage, at an enormous cost.

This insensitivity to position derives from the fact that, in contrast to processes using gas pressure to evacuate the water from the bell, namely static processes sensitive to gravity, the process according to the invention creates an over-pressure by dynamic means so that the gas pocket inside the bell is independent of the position, with only the mass flow of gas increasing with depth. This dynamic pressure is applied circumferentially and independently of the position of the bell in space, with only the gas pocket being sensitive to this positioning, but as the differential pressure may be low relative to the water pressure, the influence is not an obstacle.

Trials have been carried out with this process, using a rotatable "Plexiglas" or "Perspex" (registered Trade Marks) bell of 6cm diameter to weld constructional steel plates 5mm thick. The welding was carried out one or two passes, one on each side of the plates, with the aid of a tungsten electrode and feeding welding argon.

The electrode, connected to the positive pole of a source of direct current, was fed with a current of 150 A for the first pass and 100 A for the second pass. The speed of advance of the torch was 7 cm/min in the two cases and the argon flow was 28 l/min. The speed of the bell was about 2500 r.p.m. and the space between the edge of the bell and the plate was 1.5 to 2mm, the arc having a length of 2.5 mm. Fig. 7 shows a metallographic representation of the weld obtained. Hardness measurements on this weld gave results varying from 216 to 303 μHV measured with a weight of 50 g, the hardness of the welded steel plates being about 230 μHV. Furthermore, the welds obtained by the process according to the invention show practically no porosity, as proved by the metallographic representation, this being a defect frequently encountered in welds made under water. Finally, the very good uniformity of the weld seam should be noted.

Further trials were carried out with a fixed bell, creating the vortex by jets as in Fig. 3. These trials demonstrated that it was possible to obtain substantially the same conditions as with the rotating bell by maintaining the edge of the bell at a distance of 2 to 4 mm from the surface.

The process described may equally be applied to other underwater operations, and notably to oxyacetylent cutting, said-blasting or grit-blasting, and generally to any operation on a submerged surface which has to be cleared of liquid.

In a modification, the entire bell 7 or 7a, or at least the part defining the bell opening, may equally be constructed of a transparent or opaque flexible material such as polyethylene or rubber, for example. The advantage of this modification is to enable the bell to be adapted to surface irregularities or to a non-flat surface such as the curvature of a pipe, for example. This advantage may also be obtained with the aid of the modification of Fig. 4.

WHAT WE CLAIM IS:—

1. A process for replacing, with a volume of gas, a corresponding volume of liquid in a submerged enclosure surrounded by a bell of which the internal space has an axis of rotational symmetry, and a surface disposed facing the opening in said bell, wherein said volume of liquid is expelled by increasing its pressure relative to the pressure of the surrounding liquid, characterised in that the mass of liquid contained in the bell is given a vortex movement substantially coaxial to the said axis of the bell, and at least one escape passage is provided in proximity to the edge of said bell to force the liquid to escape from said bell by centrifugation, and gas under pressure is simultaneously fed into said bell.

2. An arc welding process, for welding below the surface of a liquid, wherein the liquid adjoining a surface to be welded is replaced with gas by the process claimed in Claim 1, the surface to be welded being disposed facing the opening of the bell, and the welding arc is formed in the volume of gas created inside the bell.

3. A process as claimed in claim 1 or 2 wherein the vortex movement is produced by rotation of the bell.

4. A process as claimed in claim 1 or 2 wherein the vortex movement is produced by tangential admission of a fluid into the bell.

5. The use of the process claimed in claim 1 for effecting an arc welding operation on said surface facing the opening of said bell, the arc being formed in the volume of gas created inside said bell.

6. A device for effecting the process claimed in claim 1 comprising a bell, a conduit for connecting this bell to a source of gas under pressure, and means for creating a vortex movement of the liquid contained in the bell.

7. A device as claimed in claim 6, in which said means for creating the vortex movement of the liquid are constituted by said bell mounted rotatably about its said axis, a drive element and a member rigid with said bell to couple said drive element with said bell and adapted to apply a torque to said bell about said axis.

8. A device as claimed in claim 6 in which said bell is provided with a feed conduit intended for connection to a source of water under pressure, said conduit opening into an annular chamber provided in the upper part of said bell, said chamber being connected to the lower part of said bell through an annular blade arrangement, the blades of which are positioned in such a manner as to give the water passing through this chamber towards the lower part of the bell a vortex movement centred about the said axis of said bell.

9. A device as claimed in claim 6, 7 or 8 in which at least that part of the bell bordering its opening is of a flexible material.

10. A device as claimed in claim 6, 7 or 8 in which the edge of said bell comprises a ring of hairs directed substantially parallel to the said axis of said bell.

11. A device as claimed in any of claims 6 to 10 in which a fixed wall extends substantially radially from said bell to interrupt the helical trajectory of the gas bubbles leaving the bell.

12. A device according to claim 6, substantially as herein described with reference to Fig. 2, Fig. 3 or Fig. 2 as modified by Fig. 4 of the accompanying drawings.

MARKS & CLERK,
Chartered Patent Agents,
57—60 Lincolns Inn Fields,
London, WC2A 3LS.
Agents for the Applicants.

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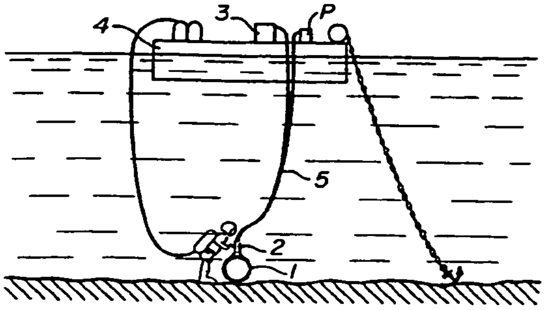


FIG. 1

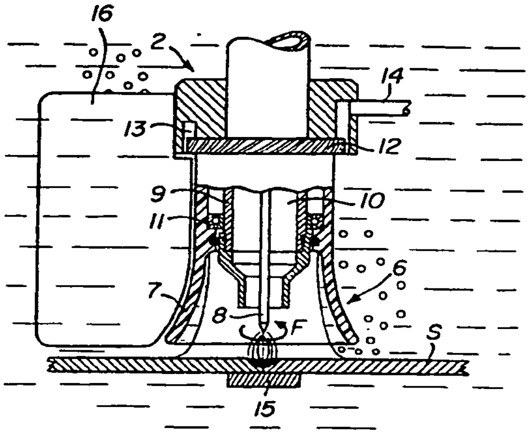


FIG. 2

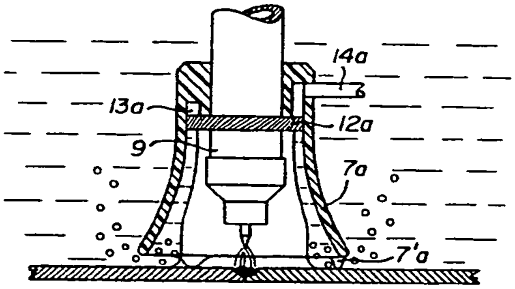


FIG. 3

FIG. 4

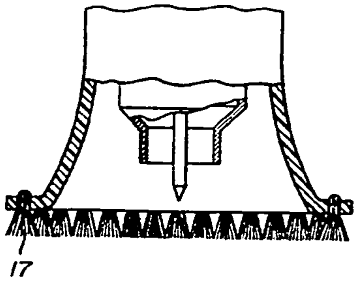


FIG. 5

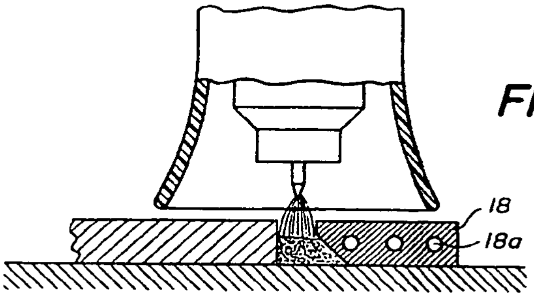
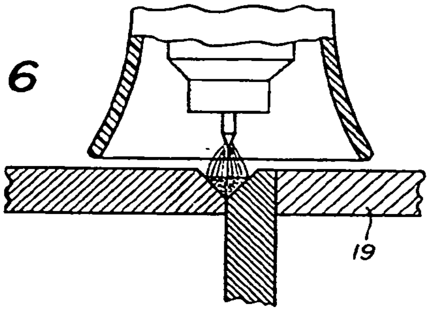


FIG. 6



1532182 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

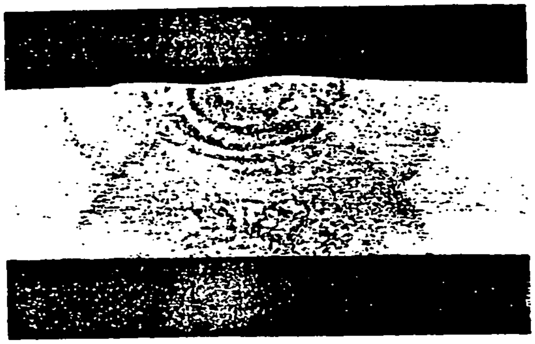


FIG. 7